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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE NATURE, MANNER OF CONVEYANCE AND MEANS OF PREVENTION OF INFANTILE PARALYSIS[1]

THE Rockefeller Institute for Medical Research has been appealed to by so many physicians and laymen for information and advice on the subject of infantile paralysis, that it has seemed desirable to relate the facts of present knowledge concerning certain highly pertinent aspects of the disease, together with deductions of practical importance derived from them.

Nature

Infantile paralysis is an infectious and communicable disease which is caused by the invasion of the central nervous organs —the spinal cord and brain—of a minute, filterable microorganism which has now been secured in artificial culture and as such is distinctly visible under the higher powers of the microscope.

Location of the Microorganism or Virus in the Sick

The virus of infantile paralysis, as the microorganism causing it is termed, exists constantly in the central nervous organs and upon the mucous membrane of the nose and throat and of the intestines in persons suffering from the disease; it occurs less frequently in the other internal organs, and it has not been detected in the general circulating blood of patients.

Location of the Virus in Healthy Persons

Although the microorganism of infantile paralysis is now known, the difficulties attending its artificial cultivation and identification under the microscope are such as

[1] Substance of an address before New York Academy of Medicine, July 13, 1916.

to make futile the employment of ordinary bacteriological tests for its detection. Nevertheless, the virus can be detected by inoculation tests upon monkeys, which animals develop a disease corresponding to infantile paralysis in human beings. In this manner the fact has been determined that the mucous membrane of the nose and throat of healthy persons who have been in intimate contact with acute cases of infantile paralysis may become contaminated with the virus, and that such contaminated persons, without falling ill themselves, may convey the infection to other persons, chiefly children, who develop the disease.

Relation of Virus to Types of the Disease

The virus has, apparently, an identical distribution irrespective of the types or severity of cases of infantile paralysis. Whether the cases correspond with the so-called abortive forms of the disease in which definite paralysis of the muscles does not occur at all, or is so slight and fleeting as often to escape detection; whether they correspond with the meningeal forms in which the symptoms resemble those of acute meningitis with which muscular paralysis may or may not be associated; or whether they consist of the familiar paralytic condition, the virus is present not only within the nervous organs, but also upon the mucous membranes of the nose, throat and intestines.

Escape of the Virus from the Body

Microorganisms which convey disease escape from the body of an infected individual in a manner enabling them to enter and multiply within fresh or uninfected individuals in such a manner as to cause further disease. The virus of infantile paralysis is known to leave the infected human body in the secretions of the nose, throat and intestines. It also escapes from contaminated healthy persons in the secretions of the nose and throat. Whether it ever leaves the infected body in other ways is unknown. At one time certain experiments seemed to show that biting insects and particularly the stable fly might withdraw the virus from the blood of infected persons and inoculate it into the blood of healthy persons. But as the virus has never been detected in the blood of human beings and later experiments with the stable fly have not confirmed the earlier ones, this means of escape of the virus must be considered doubtful. On the other hand, it has been shown by experiments on animals, so that the same facts should be regarded as applicable to human beings, that the virus seeks to escape from the body by way of the nose and throat, not only when inoculation takes place through these membranes, but also when the inoculation is experimentally made into the abdominal cavity, the blood, or the brain itself. From this it is concluded that the usual means of escape of the virus is by way of the ordinary secretions of the nose and throat and, after swallowing these, with the discharges of the intestines.

Entrance of the Virus into the Body

The virus enters the body, as a rule if not exclusively, by way of the mucous membrane of the nose and throat. Having gained entrance to those easily accessible parts of the body, multiplication of the virus occurs there, after which it penetrates to the brain and spinal cord by way of the lymphatic channels which connect the upper nasal membrane with the interior of the skull. Whether the virus ever enters the body in any other way is unknown. Certain experiments already alluded to make it possible that it may be inoculated into the blood by insects, and other experiments have shown that under peculiar and extraordinary conditions, it may in mon-

keys enter through the intestines. But while the latter two modes of infection may operate sometimes, observations upon human cases of infantile paralysis and upon animals all indicate that the main avenue of entrance of the virus into the body is by way of the upper respiratory mucous membrane—that is, the membrane of the nose and throat.

Resistance of the Virus

The physical properties of the virus of infantile paralysis adapt it well for conveyance to the nose and throat. Being contained in their secretions, it is readily distributed by coughing, sneezing, kissing, and by means of fingers and articles contaminated with these secretions, as well as with the intestinal discharges. Moreover, as the virus is thrown off from the body mingled with the secretions, it withstands for a long time even the highest summer temperatures, complete drying, and even the action of weak chemicals, such as glycerin and carbolic acid, which destroy ordinary bacteria. Hence mere drying of the secretions is no protection; on the contrary as the dried secretions may be converted into dust which is breathed into the nose and throat, they become a potential source of infection. The survival of the virus in the secretions is favored by weak daylight and darkness, and hindered by bright daylight and sunshine. It is readily destroyed by exposure to sunlight.

Conveyance by Insects

Since epidemics of infantile paralysis always arise during the period of warm or summer weather, they have been thought of as possibly being connected with or dependent on insect life. The blood-sucking insects have especially come under suspicion. Experiments have been made with biting flies, bed-bugs, mosquitoes, and with lice. Neither mosquitoes nor lice seem able to take the virus from the blood of infected monkeys or to retain it for a time in a living state. In one instance, bed-bugs have been made to take up the virus from the blood of monkeys, but they did not convey it by biting to healthy monkeys. Certain experiments did indicate that the biting stable fly could both withdraw the virus from the blood of infected and reconvey it to the blood of healthy monkeys, which became paralyzed. But more recent studies have failed to confirm the earlier ones. Moreover, experimentally inoculated monkeys differ in one way from human beings suffering from infantile paralysis, for while the virus may appear in the blood of the former, it has never been detected in the blood of the latter. The ordinary or domestic fly may become contaminated with the virus contained in the secretions of the body and serve as the agent of its transportation to persons and to food with which they come into contact. Domestic flies experimentally contaminated with the virus remain infective for 48 hours or longer. While our present knowledge excludes insects from being active agents in the dissemination of infantile paralysis, they nevertheless fall under suspicion as being potential mechanical carriers of the virus of that disease.

Conveyance by Domestic Animals

The attention which the recent epidemic of infantile paralysis has drawn to the diseases attended by paralysis has led to the discovery that domestic animals and pets are subject to paralytic diseases. The animals which have especially come under suspicion as possibly distributing the germ of infantile paralysis are poultry, pigs, dogs, and cats. But in isolated instances, sheep, cattle, and even horses have been suspected. All these kinds of animals are subject to diseases in which paralysis of the legs and other parts of the body sometimes

appear. In not a few instances, paralytic diseases among poultry or pigs have been noted to coincide with the appearance of cases of infantile paralysis on a farm or in a community. Experimental studies have, however, excluded the above-mentioned animals from being carriers of the virus of infantile paralysis. The paralytic diseases which they suffer have long been known and are quite different from infantile paralysis. Their occurrence may be coincidental; in no instance investigated has one been found to be responsible for the other.

Routes of Travel

Studies carried out in various countries in which infantile paralysis has been epidemic all indicate that, in extending from place to place or point to point, the route taken is that of ordinary travel. This is equally true whether the route is by water or land, along a simple highway or the line of a railroad. In other words, the evidence derived from this class of studies confirms the evidence obtained from other sources in connecting the distributing agency intimately with human beings and their activities.

Survival of the Virus in the Infected Body

The virus of infantile paralysis is destroyed in the interior of the body more quickly and completely than, in some instances, in the mucous membrane of the nose and throat. It has been found in monkeys, in which accurate experiments can be carried out, that the virus may disappear from the brain and spinal cord within a few days to three weeks after the appearance of the paralysis, while at the same time it is still present upon the mucous membranes mentioned. The longest period after inoculation in which the virus has been detected in the mucous membrane of the nose and throat of monkeys is six months. It is far more difficult to detect the human than the monkey carriers of the virus since, as directly obtained from human beings, the virus displays a low degree of infectivity for monkeys; while, once adapted to monkeys, the virus becomes incredibly active, so that minute quantities are capable of ready detection by inoculation tests. Yet in an undoubted instance of the human disease, the virus was detected in the mucous membrane of the throat five months after its acute onset. Hence we possess conclusive evidence of the occurrence of occasional chronic human carriers of the virus of infantile paralysis.

Fluctuation in Epidemics

Not all epidemics of infantile paralysis are equally severe. Indeed great variations or fluctuations are known to occur not only in the number of cases, but also in the death rate. The extremes are represented by the occasional instances of infantile paralysis known in every considerable community and from which no extension takes place, and the instances in which in a few days or weeks the number of cases rises by leaps and bounds into the hundreds, and the death rate reaches 20 per cent. or more of those attacked. While all the factors which determine this discrepancy are not known, certain of them have become apparent. A factor of high importance is the infective power or potency, or technically stated the virulence, of the microorganism or virus causing the disease. This virus is subject to fluctuations of intensity which can best be illustrated by an example. The virus as ordinarily present in human beings even during severe epidemics has low infective power for monkeys. But by passing it from monkey to monkey, it tends to acquire after a variable number of such passages an incredible activity. However, occasional samples of the human virus refuse to be thus intensified. But once rendered

highly potent, the virus may be passed from monkey to monkey through a long but not indefinite series. Finally, in some samples of the virus at least a reverse change takes place—the virus begins to lose its virulence until it returns to the original or even to a diminished degree of infective power. In this respect the behavior of the virus corresponds to the onset, rise and then the fall in number and severity of cases as observed in the course of epidemics of infantile paralysis and other epidemic diseases. Hence either a new active specimen of the virus may be introduced from without which, after a certain number of passages from person to person, acquires a high potency; or a specimen of virus already present and left over from a previous epidemic after a resting period and similar passages, again becomes active and reaches an infective power which equals or even exceeds that originally possessed. Another but more indefinite factor relates to the degree of susceptibility among children and others affected which at one period may be greater or less than at another.

Varying Individual Susceptibilities

Not all children and relatively few adults are susceptible to infantile paralysis. Young children are more susceptible generally speaking than older ones; but no age can be said to be absolutely insusceptible. When several children exist in a family or in a group, one or more may be affected, while the others escape or seem to escape. The closer the family or other groups are studied by physicians, the more numerous it now appears are the number of cases among them. This means that the term infantile paralysis is a misnomer, since the disease arises without causing any paralysis whatever, or such slight and fleeting paralysis as to be difficult of detection. The light or abortive cases, as they are called, indicate a greater general susceptibility than has always been recognized; and their discovery promises to have far-reaching consequences in respect to the means employed to limit the spread or eradicate foci of the disease.

Period of Incubation

Like all other infectious diseases, infantile paralysis does not arise at once after exposure, but only after an intervening lapse of time called the period of incubation. This period is subject to wide limits of fluctuation: in certain instances it has been as short as two days, in others it has been two weeks or possibly even longer. But the usual period does not exceed about eight days.

Period of Infectivity

Probably the period at which the danger of communication is greatest is during the very early and acute stage of the disease. This statement must be made tentatively since it depends on inference, based on general knowledge of infection, rather than on demonstration. Judging from experiments on animals, the virus tends not to persist in the body longer than four or five weeks except in those exceptional instances in which chronic carriage is developed. Hence cases of infantile paralysis which have been kept under supervision for a period of six weeks from the onset of the symptoms may be regarded as practically free of danger.

Protection by Previous Attack

Infantile paralysis is one of the infectious diseases in which insusceptibility is conferred by one attack. The evidence derived from experiments on monkeys is conclusive in showing that an infection which ends in recovery gives protection from a subsequent inoculation. Observations upon human beings have brought out the same

fact, which appears to be generally true, and to include all the forms of infantile paralysis, namely the paralytic, meningeal, or abortive, which all confer immunity.

Basis of the Immunity

The blood of normal persons and monkeys is not capable of destroying or neutralizing the effect of the virus of infantile paralysis. The blood of persons or monkeys who have recovered from the disease is capable of destroying or neutralizing the effect of the virus. The insusceptibility or immunity to subsequent infection, whether occurring in human beings after exposure or monkeys after inoculation, rests on the presence of the destroying substances, the so-called immunity bodies, which arise in the internal organs and are yielded to the blood. So long as these immunity bodies persist in the body, protection is afforded; and their presence has been detected twenty years or even longer after recovery from infantile paralysis. Experiments have shown that the immunity bodies appear in the blood in the course of even the mildest attack of the disease, which fact explains why protection is afforded irrespective of the severity of the case.

Active Immunization

Protection has been afforded monkeys against inoculation with effective quantities of the virus of infantile paralysis by previously subjecting them to inoculation with sub-effective quantities or doses of the virus. By this means and without any evident illness or effect of the protective inoculation, complete immunity has been achieved. But the method is not perfect since in certain instances not only was immunity not obtained, but unexpected paralysis intervened. In the instances in which protection was accomplished, the immunity bodies appeared in the blood.

Passive Protection

By transferring the blood of immune monkeys to normal or untreated ones, they can be rendered insusceptible or immune, and the immunity will endure for a relatively short period during which the passively transferred immunity bodies persist. The accomplishment of passive immunization is somewhat uncertain, and its brief duration renders it useless for purposes of protective immunization.

Serum Treatment

On the other hand, a measure of success has been achieved in the experimental serum treatment of inoculated monkeys. For this purpose blood serum derived either from recovered and protected monkeys or human beings has been employed. The serum is injected into the membranes about the spinal cord, and the virus is inoculated into the brain. The injection of serum must be repeated several times in order to be effective. Use of this method has been made in a few instances in France where the blood serum derived from persons who had recovered from infantile paralysis has been injected into the spinal membranes of persons who have just become paralyzed. The results are said to be promising. Unfortunately, the quantity of the human immune serum is very limited, and no other animals than monkeys seem capable of yielding an immune serum and the monkey is not a practicable animal from which to obtain supplies.

Drug Treatment

The virus of infantile paralysis attacks and attaches itself to the central nervous organs. Hence it is reached not only with difficulty because nature has carefully protected those sensitive organs from injurious materials which may gain access to the blood, but it must be counteracted by substances and in a manner that will not them-

selves injure those sensitive parts. The ideal means to accomplish this purpose is through the employment of an immune serum, since serums are among the least injurious therapeutic agents. The only drug which has shown any useful degree of activity is hexamethylenamin which is itself germicidal, and has the merit of entering the membranes, as well as the substance of the spinal cord and brain in which the virus is deposited. But experiments on monkeys have shown this chemical to be effective only very early in the course of the inoculation and only in a part of the animals treated. Efforts to modify and improve this drug by chemical means have up to the present been only partially successful. The experiments have not yet reached the point where the new drugs are applicable to the treatment of human cases of infantile paralysis.

Practical Deductions and Applications

1. The chief mode of demonstrated conveyance of the virus is through the agency of human beings. Whether still other modes of dissemination exist is unknown. According to our present knowledge, the virus leaves the body in the secretions of the nose and throat and in the discharges from the intestines. The conveyers of the virus include persons ill of infantile paralysis in any of its several forms and irrespective of whether they are paralyzed or not, and such healthy persons who may have become contaminated by attendance on or association with the ill. How numerous the latter class may be is unknown. But all attendants on or associates of the sick are suspect. These healthy carriers rarely themselves fall ill of the disease; they may, however, be the source of infection in others. On the other hand, the fact that infantile paralysis is very rarely communicated in general hospitals to other persons, whether doctors, nurses or patients, indicates that its spread is subject to ready control under restricted and supervised sanitary conditions.

2. The chief means by which the secretions of the nose and throat are disseminated are through the act of kissing, coughing or sneezing. Hence during the prevalence of an epidemic of infantile paralysis, care should be exercised to restrict the distribution as far as possible through these common means. Habits of self-denial, care and cleanliness and consideration for the public welfare can be made to go very far in limiting the dangers from these sources.

Moreover, since the disease attacks by preference young children and infants, in whom the secretions from the nose and mouth are wiped away by mother or nurse, the fingers of these persons readily become contaminated. Through attentions on other children or the preparation of food which may be contaminated, the virus may thus be conveyed from the sick to the healthy. The conditions which obtain in a household in which a mother waits on the sick child and attends the other children are directly contrasted with those existing in a well-ordered hospital: the one is a menace, the other a protection to the community. Moreover, in homes the practise of carrying small children about and comforting them is the rule, through which not only the hands, but other parts of the body and the clothing of parents may become contaminated.

3. Flies also often collect about the nose and mouth of patients ill of infantile paralysis and feed on the secretions, and they even gain access to the discharges from the intestines in homes unprotected by screens. This fact relates to the domestic fly, which, becoming grossly contaminated with the virus, may deposit it on the nose and mouth of healthy persons, or upon food or eating utensils. To what extent the biting stable

fly is to be incriminated as a carrier of infection is doubtful; but we already know enough to wish to exclude from the sick, and hence from menacing the well, all objectionable household insects.

Food exposed to sale may become contaminated by flies or from fingers which have been in contact with secretions containing the virus; hence food should not be exposed in shops and no person in attendance upon a case of infantile paralysis should be permitted to handle food for sale to the general public.

4. Protection to the public can be best secured through the discovery and isolation of those ill of the disease, and the sanitary control of those persons who have associated with the sick and whose business calls them away from home. Both these conditions can be secured without too great interference with the comforts and the rights of individuals.

In the first place where homes are not suited to the care of the ill so that other children in the same or adjacent families are exposed, the parent should consent to removal to hospital in the interest of the sick child itself, as well as in the interest of other children. But this removal or care must include not only the frankly paralyzed cases, but also the other forms of the disease. In the event of doubtful diagnosis, the aid of the laboratory is to be sought since even in the mildest cases changes will be detected in the cerebrospinal fluid removed by lumbar puncture. If the effort is to be made to control the disease by isolation and segregation of the ill, then these means must be made as inclusive as possible. It is obvious that in certain homes isolation can be carried out as effectively as in hospitals.

But what has been said of the small incidence of cases of the disease among the hospital personnel and those with whom they come into contact, indicates the extent to which personal care of the body by adults and responsible people can diminish the menace which those accidentally or unavoidably in contact with the ill are to the community. Care exercised not to scatter the secretions of the nose and throat by spitting, coughing and sneezing, the free use of clean handkerchiefs, cleanliness in habits affecting especially the hands and face, changes of clothes, etc., should all serve to diminish this danger.

In the end, the early detection and isolation of the cases of infantile paralysis in all of its forms, with the attendant control of the households from which they come, will have to be relied upon as the chief measure of staying the progress of the epidemic.

5. The degree of susceptibility of children and other members of the community to infantile paralysis is relatively small and is definitely lower than to such communicable diseases as measles, scarlet fever, and diphtheria. This fact in itself constitutes a measure of control; and while it does not justify the abatement of any practicable means which may be employed to limit and suppress the epidemic, it should tend to prevent a state of over-anxiety and panic from taking hold of the community.

6. A percentage of persons, children particularly, die during the acute stage of the disease. This percentage varies from five in certain severe epidemics to twenty in others. The average death rate of many epidemics has been below 10 per cent. A reported high death rate may not be actual, but only apparent, since in every instance the death will be recorded, while many cases which recover may not be reported at all to the authorities. In the present instance it is too early in the course of the epidemic to calculate the death rate, which may prove to be considerably lower than it now seems to be.

7. Of those who survive, a part make complete recoveries, in which no crippling whatever remains. This number is greater than is usually supposed, because it includes not only the relatively large number of slight or abortive cases, but also a considerable number of cases in which more or less of paralysis was present at one time. The disappearance of the paralysis may be rapid or gradual—may be complete in a few days or may require several weeks or months.

The remainder, and unfortunately not a small number, suffer some degree of permanent crippling. But even in this class, the extent to which recovery from the paralysis may occur is very great. In many instances the residue of paralysis may be so small as not seriously to hamper the life activities of the individual; in others in whom it is greater it may be relieved or minimized by suitable orthopedic treatment. But what it is imperative to keep in mind is that the recovery of paralyzed parts and the restoration of lost muscular power and function is a process which extends over a long period of time—that is, over months and even years. So that even a severely paralyzed child who has made little recovery of function by the time the acute stage of the disease is over, may go on gaining for weeks, months, and even years until in the end he has regained a large part of his losses. Fortunately, only a very small number of the attacked are left severely and helplessly crippled. Lamentable as it is that even one should be so affected, it is nevertheless a reassurance to know that so many recover altogether and so much of what appears to be permanent paralysis disappears in time.

There exists at present no safe method of preventive inoculation or vaccination, and no practicable method of specific treatment. The prevention of the disease must be accomplished through general sanitary means; recovery from the disease is a spontaneous process which can be greatly assisted by proper medical and surgical care. Infantile paralysis is an infectious disease, due to a definite and specific microorganism or virus; recovery is accomplished by a process of immunization which takes place during the acute period of the disease. The tendency of the disease is toward recovery and it is chiefly or only because the paralysis in some instances involves those portions of the brain and spinal cord which control respiration or breathing and the heart's action, that death results.

Finally, it should be added that not since 1907, at which time the great epidemic of infantile paralysis, or poliomyelitis, appeared in this country, has the country or this state or city been free of the disease. Each summer since has seen some degree of accession in the number of the cases; the rapid rise in the number of cases this year probably exceeds that of any previous year. But it must be remembered that in 1908 several thousand cases occurred in the greater city—possibly indeed many cases of and deaths due to the disease were never reported as such. Hence the present experience, severe and serious as it is, is not something new; the disease has been severely epidemic before and was brought under control. The knowledge regarding it now is far greater than it was in 1908; and the forces of the city which are dealing with the epidemic are probably better organized and in more general cooperation than ever before. The outlook, therefore, should not be regarded as discouraging.

SIMON FLEXNER

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THE BASIS OF INDIVIDUALITY IN ORGANISMS. A DEFENSE OF VITALISM[1]

In his presidential address before the Zoological Section of the British Association for the Advancement of Science, Professor D'Arcy W. Thompson ('11) said:

> While we keep an open mind on this question of vitalism, or while we lean, as so many of us now do, or even cling with a great yearning, to the belief that something other than the physical forces animates the dust of which we are made, it is rather the business of the philosopher than of the biologist, or of the biologist only when he has served his humble and severe apprenticeship to philosophy, to deal with the ultimate problem. It is the plain bounden duty of the biologist to pursue his course unprejudiced by vitalistic hypotheses, along the road of observation and experiment, according to the accepted discipline of the natural and physical sciences. . . . It is an elementary scientific duty, it is a rule that Kant himself laid down, that we should explain, just as far as we possibly can, all that is capable of such explanation, in the light of the properties of matter and of the forms of energy with which we are already acquainted.

This quotation will serve as a text for, and the keynote of, the remarks I shall make this morning. For to Professor Thompson's thesis I heartily subscribe. And if in what I say any statement seems irreconcilable with his assertions, such inconsistency is unintentional and, as I believe, apparent rather than real. But that all will follow me as sympathetically as I assume you have listened to the remarks I have quoted is more than I venture to hope.

As I interpret the topic under discussion, two main problems are involved:

1. The scientific problem of vitalism and mechanism.
2. The philosophical problem of idealism and materialism.

[1] An address delivered before the American Society of Zoologists and Section F (Zoology) of the American Association for the Advancement of Science at Columbus, Ohio, December 29, 1915, in a symposium upon "The Basis of Individuality in Organisms."

I. THE SCIENTIFIC PROBLEM OF INDIVIDUALITY —VITALISM VS. MECHANISM

The scientific problem of vitalism *vs.* mechanism has recently been formulated by Jennings ('14, p. 17) as follows:

"Is individuality a phenomenon not determined by the perceptual conditions, but requiring to account for it the agency of a non-perceptual agent?" To the discussion of this problem we shall first turn.

The analysis of the concept of individuality—at least human individuality—reveals that individuality presents itself in two aspects, distinguishable in thought if not in reality:

1. The objective or physical aspect of individuality;
2. The subjective or psychical aspect of individuality.

Turning our attention, then, to

1. *The Objective or Physical Aspect of Individuality.*—In this aspect, the organic individual is a persistent, complex, coherent and spatially-distinct whole, consisting of interdependent parts. The organic individual is distinguishable from the inorganic individual by the chemical process of proteid metabolism, growth by the intussusception of new material, and by the process of reproduction. In the higher animals and man integration of the highly differentiated body is effected through the mechanism of a central nervous system and the secretions (hormones) of certain glands. As a physical body the organic individual is subservient to the laws of sequential mechanistic causation, and derives all its energy directly or indirectly from the sun.

2. *The Subjective or Psychical Aspect of Individuality.*—Eaeh organic individual—at least in the case of man—is directly aware of a series of "states" or "moments"

of consciousness, determined directly or indirectly through the agency of the various senses. Within this "wave of consciousness" are presented all of the experiences which together make up the drama of life of the individual. While consciousness may not be defined (except in terms of itself), it may be described.

To other individuals this "inner life" of each individual is non-perceptual, but may —in the case of man—be described through language or other physical expression. To the fact of its non-perceptuality to others is due the "seeming unreality of the inner life."

All the "data" of science are data of conscious experience. The "experiences" of the individual fall into two chief classes:

(*a*) Those experiences which appear as manifestations of the properties of matter and which may be described or interpreted in terms of matter in motion—spatial phenomena.

(*b*) Those experiences such as emotions which do not have spatial attributes—non-spatial phenomena.

But consciousness—the psychical aspect of the individual—is not merely a string of sequential "moments" of consciousness. Its most essential characteristic is its purposeful unity. There is something which unifies, relates and orders the states of consciousness in each individual. This "something"—the "Ego" or "Will"—is able to dislocate in time the order of sequence of past experiences.

Although mind and body—the physical and psychical—are distinguishable in thought, there is no scientific evidence that they are separate in reality.

The laws of sequential causation apply to mental states just as to physical ones.

Mental processes are among the most reliable phenomena in Nature (Glaser, '12).

The problem of vitalism is: How are we to interpret the behavior of this psycho-physical individual?

Two historical answers have been given to the scientific problem of vitalism—(1) the answer of mechanism; (2) the answer of vitalism.

1. *The Mechanistic Interpretation of Individuality.*—Mechanism is the doctrine that all phenomena—living and lifeless—are manifestations of the properties of matter in motion. According to mechanism, sequential physical causation is universal and involves only those forms of energy recognized by physics and chemistry. Such sequences may be either (*a*) mechanical or reversible, like those of machines; or, (*b*) physical or non-reversible, like the radiation of heat. According to mechanism, all vital sequences conform to one or the other of these two types. Individual behavior is —directly or indirectly—the expression of the energy liberated during the chemical process of metabolism. Mechanism recognizes no alien influx or interference of "souls" or "entelechies" in the endless series of physical sequences.

If we let B represent the body (physical individual), and (w) represent the mechanistic view of will (consciousness) as an epiphenomenon, the mechanistic formula of the individual is $B(w)$.

2. *The Vitalistic Interpretation of Individuality.*—According to vitalism the mechanistic formula is inadequate to nature and to life. In the living body—at least in the case of man—sequential causation involves another factor or agency than those recognized by chemists and physicists. This non-physical (non-spatial) "vitalistic" agency modifies the behavior of the living organism so that, from a knowledge of the physical conditions only, "it would be impossible to predict what will happen under any given set of physical conditions." According to vitalism, the will or

other vitalistic agency "so interacts with physical conditions as to give a physical result that is diverse from the result that would be produced under the same antecedent conditions without consciousness" (Jennings).

According to vitalism the formula for the organic individual is either (*a*) the dualistic formula $W + B$ (W representing the will or vitalistic agency, and B the body or physical aspect of individuality); or, (*b*) the idealistic formula $W(b)$ (W representing the will or vitalistic agency, and (b) the phenomenal body).

The divergence between the mechanistic and the vitalistic interpretation of individuality is, therefore, very great, constituting in fact "the greatest schism in human thought." "The vitalist sees in individuality—personality or the self—a coordinating center and synthetic activity contrasted with all other agencies in nature—a real creative power. While the mechanist sees only what he sees in any other receptive object, a center where many forces cross, checking, intensifying, neutralizing or transforming one another without loss or addition" (Palmer, '11).

Which of these two interpretations are we to accept? Are the two views wholly irreconcilable? Is the problem of individuality, after all, an insoluble one?

Opinions differ. The literature is voluminous, for this is the problem of the ages. Wholly unprejudiced discussion is rare. Among scientific men the cause of vitalism has suffered because of its association historically with theological dualism, while on the other hand many vitalists have opposed mechanism upon the mistaken belief that mechanism is identical with—or demands the postulate of—philosophical materialism.

Among the divergent views expressed, a few may be mentioned which are indicative of the trend of present opinion concerning the problem of individuality—the problem of vitalism and mechanism.

Professor L. J. Henderson finds that the discussion of the vitalistic problem has led to the following dilemma:

Assertion 1.—Common sense—as represented by those who make a study of the movements of physical bodies—leads to the conclusion that all physical events are subject to the laws of physical causation.

Assertion 2.—Common sense—as represented by those who make a study of the behavior of men in history—leads to the conclusion that some physical events are not subject to the laws of physical causation alone, but that will or caprice has affected the course of historical events.

Now since both assertions appear to be equally valid in common sense experience, and as both opinions can not be true at the same time, and as there seems to be no immediate prospect of their reconciliation, Professor Henderson turns away his attention to more promising lines of investigation.

William MacDougall ('11) discovers the same dilemma. On the ground, however, that the issues involved are too important to admit of neutrality, he casts in his lot with the vitalists. His book on "Body and Mind" is a strong defense of the vitalistic thesis. Other recent valuable contributions to the formulation and elucidation of the vitalistic problem have been made by Ward ('03), Driesch ('14), Bütschli ('01), Palmer ('11), Bergson ('11), Jennings ('14), Lovejoy ('09), Spaulding ('09), Sumner ('10), Woodruff ('11), Ritter ('11), Glaser ('12), R. McDougall ('13), R. S. Lillie ('14), A. J. Balfour ('79), Stout ('05), Lloyd Morgan ('05), Paulsen ('95), Höffding ('05), Haldane ('08), Ladd ('09), Bosanquet ('12), Strong ('03), Conklin ('15), Loeb ('11), James ('07).

Jennings ('14, p. 20), taking up the problem as a scientific problem by the method of radically experimental analysis, reaches the following conclusion:

> The phenomena of life require nowhere the differential action of a non-physical agent. Their occurrence is bound up throughout with that of physical and material phenomena. Diversities in them are determined by antecedent physical and material diversities. They show, therefore, the same type of relations to each other, to physical conditions, and to matter, as do the phenomena called physical. But they include phenomena not found in the non-living, and therefore to be known only through study of the living. Such is conscious individuality, the highest manifestation from the interwoven tissue that makes up the experienced universe.

That is to say, Jennings comes to the conclusion that the problem of vitalism has no experimental meaning. With this opinion presumably the majority of biologists will agree.

Is this, then, the final answer of science (physical science) to the problem of the ages? Is the case of Vitalism vs. Mechanism closed and the verdict rendered in behalf of the defendant? Will the vitalist accept the verdict? We may anticipate that he will not, if we are to judge on the basis of past experience. In the past when verdicts have been rendered against him—as in the Vital Spirits Case, the Urea Case, the Vital Force Case, etc., he has always shifted his ground, and although defeated in every trial, he has always been able to secure a rehearing of his case in the same court—the court of physical science. Will he do so now? I am of the opinion that he will.

But on what grounds can he make an appeal? He can scarcely convince a scientific jury that his case has not been heard in all fairness and impartiality upon the basis of the premises made. He may not fairly claim that the experimental and analytical logical methods have been inadequate or inconclusive. So far as I can see, his only chance of securing a rehearing at the court of science or in the higher court of philosophy (as suggested by Professor Thompson, '11) would be to demonstrate that the fundamental postulates upon which his case has been previously tried have been in error, and that the conclusions reached have been based on false premises. On this ground there would seem to be sufficient justification for taking his case to the higher court of philosophy, which has jurisdiction over matters relating to fundamental postulates.

If, then, the vitalist can show that his case has been prejudiced by the philosophical assumptions made in previous trials, if it must be admitted that it makes a difference to the case of the vitalist whether it be based upon materialistic, or dualistic or idealistic postulates, and if it can be shown that the basis upon which the case has been tried has not been the only possible basis upon which it might be tried and that, in fact, it has been tried upon a wholly false basis, then the vitalist is justified in demanding a rehearing in the higher court of philosophy, which has jurisdiction over such cases. Such considerations are, I infer, the reasons for the selection of this morning's topic. And if the outcome of the discussion be the decision that the case of vitalism has been prejudiced in the past by the false premises made by the attorneys who have handled the case in the court of science, then in all fairness the vitalist should be granted the rehearing he now demands.

It has been frequently assumed in the discussion of vitalism by scientific writers that the formula of mechanism is adequate to experience. This, for example, appears to be the assumption which underlies the argument of Jennings ('14). Shall this assumption pass unchallenged? Certainly

not by the vitalist. He has challenged it again and again, holding that it is not justified in experience. This is the argument of the vitalist in brief: He asserts:

The case of vitalism is not one to be tried in the court of physical science, for it does not come within the jurisdiction of that court, since the mechanistic formula is inadequate to life. For

Physical science treats of only a part of human experience—viz., that part of human experience having spatial attributes, or which may be interpreted in terms of matter in motion.

But human experience includes phenomena without spatial attributes—phenomena which may not be interpreted in terms of matter in motion. This is recognized by the division of the sciences into the physical sciences, which deal with those phenomena having spatial attributes (or which are the manifestations of the attributes of matter in motion); and the mental sciences—psychology and philosophy and ethics—which deal more especially with non-spatial experience. But individuality (human personality) includes both classes of phenomena. The court of physical science, therefore, in trying the case of individuality is dealing with one which does not strictly come within its jurisdiction. Hence, vitalism—the case of personality—now appeals to the higher court of philosophy which tries cases relating to the fundamental postulates of both mental and physical sciences.

But is the vitalist justified in his assertion that physical science—mechanism—is inadequate to experience? Here there is decided difference of opinion. Dr. Jennings supports the "mechanistic dogma" of the universal applicability of mechanistic interpretation. For he says ('14, pp. 6–5) that mechanism is a "purely descriptive account of what is found to hold in experience." "There is no ground, theoretical or practical, for limiting scientific treatment to diversities of any particular kind (as diversities of motion)," that, in other words, the field of physical science includes the entire field of human experience. "Mechanism," therefore, is adequate to nature and to individuality. Consequently, if this position be taken, there would appear to be no reason for continuing the case of vitalism further.

I am unable to discover that any considerable number of psychologists accept Dr. Jennings's assumption. On the contrary, the great majority seem to agree with Professor Ladd when he says ('09, p. 884):

> Thinking and the cognitive judgment can never be explained—and, indeed, the facts can not even be stated—in terms of either neururgics or the mechanism of presentations.

In other words, there is doubt that psychologists would accept the assumption of Jennings of the adequacy of mechanism to experience. For the same reason, his further assumption—underlying his whole argument—that "every diversity in conscious states is accompanied by a diversity in physical conditions" may be challenged as far transcending our present knowledge. The vitalist may call attention to the fact that Dr. Jennings assumes as the basis of his argument the very point under discussion—the question in litigation—viz., the adequacy of the mechanistic formula.

But I am of the opinion that the vitalist has the best of reasons for appealing his case to a higher court on the ground that the basic philosophical assumptions upon which his case has been argued have prejudiced the case against him and have been philosophically unsound. For all who have discussed the case of vitalism in relation to individuality (personality) have made implicitly or explicitly philosophical assumptions. Indeed, the problem of the psycho-physical individual can not be dis-

cussed otherwise. W. MacDougall ('11) argues the case for vitalism on the basis of philosophical dualism. The dualistic assumption appears to underlie the "common sense" argument advanced by Professor Henderson. James Ward ('03) advocates the case of vitalism on the basis of a critical idealism (spiritualism).

That Jennings ('14, p. 18) accepts the postulate of materialism is clear from his assertion that "when the set of phenomena we call matter reaches a certain complexity, it gives rise to this particular manifestation that we call personality." In other words, unconscious matter in the course of evolution produced consciousness. Before this stage of material evolution consciousness did not exist—there was no consciousness. Matter exists before mind, but later gives rise to consciousness as a quality of an underlying substance. The real thing then is matter which indeed once existed independently of any consciousness at all. Whether there were any consciousness or not, matter would still persist. The real organic individual is the physical individual, and all its qualities—psychical and other—are manifestations of this basic material body. This tacit assumption was presumably behind the declination of Jennings ('14) to accept the two classes of conscious experience mentioned above.

Is the materialistic assumption nonvalid? Does its postulation by Jennings prejudice the case of vitalism? Is the case of vitalism "ruled out of court" and completely subverted if the materialistic postulate is admitted? Unquestionably it is. For materialism (philosophical, not scientific) is the one philosophy with which vitalism is wholly irreconcilable. To assume it, therefore, is to deny vitalism (neo-vitalism). The case doesn't have to be tried at all. But the whole contest which has been waged by vitalism has been against materialism. In opposing mechanism the vitalist has been "barking up the wrong tree." His mistake has been due to the inexcusable identification of mechanism with philosophical materialism. Vitalism has no real issue with mechanism—not at least with mechanism as a scientific method of interpretation of spatialized phenomena. But with philosophical materialism as a postulate of science the vitalist may for the best of reasons take issue. Therefore, as Paul appealed to Cæsar and to the higher court of Rome, the vitalist may with justice ask for a continuation of his case in the higher court of philosophy.

What then is the philosophical standing of the materialistic postulate? What really is basic to individuality (human personality)? Of what are we more certain—of an external world independent of consciousness and consisting of atoms or electrons in motion, or of a world of ideas, of purposes and of emotions? We therefore are compelled to consider the philosophical problem of reality and the case of vitalism becomes in the higher court of philosophy the Case of Idealism (or Dualism) *vs.* Materialism. To this, the second point of the topic under discussion, we may now turn our attention.

II. THE PHILOSOPHICAL PROBLEM OF INDIVIDUALITY—IDEALISM (OR DUALISM) VS. MATERIALISM

The problem which is now before us is the central problem of philosophy—the problem of reality. Is the materialist correct in holding that the organic individual (human personality) is in reality an aggregate of atoms or electrons which might exist independently of consciousness? Is, therefore, the formula for the individual $B(w)$?

Is the dualistic philosopher correct in asserting that the individual consists of two realities—body and mind—which are not only distinguishable in thought, but also separate in reality, although united tem-

porarily in human individuality? Is, therefore, the formula for the individual $B+W$?

Or is the idealist correct in maintaining that the individual is in reality spiritual—a Will or "Ego" with physical manifestations? Is the body of the organism an ideal (though none the less real) body—a mechanism through the agency of which the will or Ego operates? Is, therefore, the formula of individuality $W(b)$?

Upon the answer given to these questions by the philosopher will depend the future standing of vitalism in science.

The considerations which have led most philosophers and many men eminent in science to repudiate the materialistic assumption and to conclude that in ultimate analysis and in reality our world and the individual is spiritual are in brief as follows:

In the first place, the data of science are phenomena in consciousness. For anything to be outside of consciousness, therefore, is to be unknown, and hence outside of the field of science which deals with the known. To postulate an external world of atoms and electrons independent of—or outside of—consciousness is to postulate an unknowable world—a metaphysical world. It is a wholly erroneous notion that this conclusion of philosophy involves the denial of an external world—the "permanent possibility of sensation." There is indeed—to the idealist not less than to the realist—an external world which is the cause of our ideas. But this external world of ours must be a world of ideas—that is, if it is like our ideas as we believe it is. But if the objects in this external world are like our ideas, then they must be ideas. Therefore, "either the real external world is a world of ideas—an outer world of mind which each of us may in a measure comprehend through experience, or—so far as it is external and real—it is wholly unknowable" (Royce, '92). "It was Berkeley," says Lloyd Morgan ('05), "who knocked the bottom out of materialism as a philosophy so that no amount of tinkering can make it again hold water." Materialism, therefore, as a philosophy, has long been in disrepute among philosophers. It is, therefore, almost incomprehensible why an outworn and discarded philosophy should be made the basis of a scientific discussion of the problem of individuality. Are we to assume that "one assumption is just as good as another" and that it is impossible to distinguish between true and false assumptions? Does it not matter to us whether our basic assumptions are philosophically sound or not? Are the conclusions reached by modern philosophy of no concern to the biologist in the discussion of the problem of individuality?

The acceptance of the materialistic postulate by scientific men notwithstanding its philosophical disrepute appears to be due in part to the confusion of philosophical with scientific materialism, and in part to the strong prejudice against philosophical views owing to the excesses of philosophers during the romantic period. The combination of this prejudice with that against philosophy as the "handmaid" of religion makes it to-day almost impossible for philosophical arguments to receive a fair hearing in the court of physical science. How in the history of human thought the mechanistic interpretation of the phenomena of the external world became gradually transformed into a philosophy of life may best be understood by a brief statement of its genesis in the thought of the individual.

The untrained person considers the world to be just about what his senses tell him it is. Later, however, he learns to distinguish between an internal reality and an "external" reality and he finally comes to ask, "How much can I know of external reality?" He soon learns that all he can know

of the "external" world must be acquired through the senses, *i. e.*, through the physiological-psychological process. This process involves three steps: (1) The stimulus (the object in the external world); (2) The nerve disturbance (caused by the stimulus); (3) The sensation or sense impression (the result of the nerve disturbance). Through the discoveries of the chemist and the physicist he learns that all of the phenomena of the external world may be reduced to or expressed in terms of atoms or electrons in motion, rapidly in gases, less so in liquids and still less so in solids; that all chemical change involves a rearrangement of atoms, and finally that all forms of energy depend on the rapid movement of atoms. Moreover, the physiologist assures him that these assertions hold true for the living as well as for the lifeless. Thus the physical (external) universe appears to be a universe of atoms or electrons in motion.

Up to this point in his thinking our hypothetical friend has been standing on perfectly sound ice. With his conclusion there is not the slightest reason to disagree. This —the mechanistic interpretation of the physical universe—is the accepted interpretation of our generation. Its validity as a scientific hypothesis stands unchallenged. There is no reason whatever to believe that in principle it will ever be overthrown. The mechanist gets on very thin and very treacherous ice (where the philosopher is unable to follow him) when he infers that when electrons come together in certain propositions and under certain conditions consciousness would be the result. Thus he might reach the conclusion of the materialist that whether there were any consciousness at all, the dance of atoms and the material universe would go on just the same. The universe, then, he concludes, is in reality a universe of atoms and electrons independent of consciousness. Some such process of reasoning as this appears to be the usual method of the transformation of the mechanistic thinker into a materialistic philosopher. The considerations which appear to invalidate his conclusion have already been stated above.

The disproof of materialism (as a philosophy—not as a working scientific hypothesis) is at the same time the argument adduced in support of philosophical idealism (spiritualism), the status of which is so unquestioned that it has become the dominant philosophy of the twentieth century. Many scientific investigators impressed by its logical soundness have adopted it as the basis of their thought and of their interpretation of nature and of life.

That the world of science is withal a world of ideas has been appreciated by scientific thinkers scarcely less than by philosophers. "Our one certainty is the existence of the mental world," writes Huxley. "Ego is the only reality and everything else is only Ego's idea," says Charles Sedgwick Minot. "The sole reality that we are able to discover in the world is mind," says Verworn. "Our world is after all a world of individual consciousness and ideas," says Crampton. "The field of science is essentially the contents of the mind," says Karl Pearson. "The world of knowledge is of such stuff as ideas are made of," writes Josiah Royce.

Thus the basis of modern critical idealism is so sound that its position has come to be regarded as impregnable, and the arguments now used against it are not directed at its foundations, but at certain supposed logical consequences of its acceptance. Many of the arguments raised against critical idealism are based on misunderstanding. One of these is the erroneous inference that idealism is subversive of a mechanistic interpretation of the physical universe. To hear some of the arguments used against it

one would think that neither philosophy nor theology had advanced during the development of human thought. Idealism is not a doctrine of those who "wish to lay the intellect to rest on a pillow of obscure ideas," nor is it an attempt to undermine mechanistic hypotheses. Many of the objections are made by those who confuse modern critical idealism with solipsism or subjective idealism. The limits of this paper do not admit the presentation of these objections and their rebuttal. I search in vain, however, for a real, valid, scientific objection to the postulate of modern critical idealism. That it is the dominant philosophy of our generation has already been asserted.

I shall not attempt to discuss the dualistic postulate, since it has little standing among philosophers and none at all among men of science—except upon such illogical grounds as even scientific men are capable. The dualistic hypothesis, therefore, doesn't interest us. But if one were compelled to choose between the postulate of dualism and that of materialism the adoption of the former would appear to be far more rational.

It is well recognized that epiphenomenalism is but thinly disguised materialism and the arguments against the latter apply equally against the former. Of epiphenomenalism Minot ('02, p. 3) says:

> An epiphenomenon is something superimposed upon the actual phenomena having no causal relation to the further development of the process. There is no idea at all underneath the epiphenomenon hypothesis of consciousness. The hypothesis is simply an empty phrase, a subterfuge—which amounts to this—we can explain consciousness very easily by merely assuming that it does not require to be explained at all.

Says W. McDougall ('11, p. 150):

> Epiphenomenalism, though it may perhaps be consistent with the law of the conservation of energy, offends against a law that has a much stronger claim to universality, namely the law of causation itself; for it assumes that a physical process, say a molecular movement of the brain, causes a sensation, but does so without the cause passing over in any degree into the effect, without the cause spending itself in any degree in the production of the effect, namely, the sensation.

Consequently, in our discussion of the problem of individuality, we are compelled, I believe, to make our choice between philosophical materialism and idealism (spiritualism), that is to say, between mind and matter (independent of mind) as the basis of individuality. Our choice is to be made between a postulate which is philosophically disreputable and one which has been accepted by the great philosophers of recent times from Berkeley and Kant to Emerson, Royce and James; between the assumption of a wholly unknowable and metaphysical world and the indisputable assumption that our one surest reality is consciousness; between the Haeckelian riddle and the assumption that our world has moral and spiritual meaning; between a world in which the words and gestures of every individual "would have been just what they have been, the same empires would have risen and fallen, the same masterpieces of music and poetry would have been produced, the same indications of friendship and affection would have been given in the absence of consciousness" (C. Lloyd Morgan, '05), and the "common sense" view of the historian that human motives and purposes have affected the course of human events; between a fatalistic world of illusion, on the one hand, and a world in which choices are real and ideals count; between an assumption which renders untenable the great human ideas of God, freedom and immortality and one which gives these unquestionable validity.

That modern philosophy has repudiated the materialistic postulate is not surprising in the light of the considerations presented above. Its adoption by biologists as the

basis of their interpretation of personality and of life is incomprehensible unless it be assumed that biologists are strongly prejudiced against the idealistic philosophy through misunderstanding. But, since the materialistic postulate is not only philosophically unsound and wholly unnecessary for any ends which the mechanist has in view, and since it is metaphysical, unscientific and irrational—wholly inconsistent with the lives of those who make it, as Conklin ('15) has said—biologists must reject it and accept the idealistic assumption as modern philosophy has done. We need to bring back our scientific postulates to the touchstone of fact. Our biological premises have been too narrow. We live in a larger scheme of things than mechanism has been able to discover. There is more in life than is dreamed of in the materialistic philosophy.

> The world of space and time, of physical cause and effect, matter and finite mind is but a very subordinate part of reality (Royce).

The way out of the blind alley into which materialism has led us is, as D. G. Brinton has said, "not by the assumption of an entity apart from attributes; but by the indisputable truth that the laws of mechanics and motion themselves are in final analysis nothing else but laws of thought of the reasoning mind, and derive their first and only warrant from the higher reality of that mind."

In the light of such considerations and in view of the fact that the materialistic postulate has usually been the basis of the biological discussion of the problem of individuality, and in view of the fact that upon the materialistic assumption the vitalistic interpretation of life is wholly excluded and therefore has no experimental meaning, the vitalist seems not unreasonable in his demand for a rehearing of his case upon an idealistic basis. For, upon this basis, the possibility of a vitalistic interpretation is not excluded as it actually is upon the materialistic basis. Upon the idealistic premise the possibility is open that not all of individuality (personality) is spatially expressed, that is to say, mechanized. In other words, upon this assumption the contention of the vitalist may be valid—viz., that from a knowledge of the physical conditions alone "it would be impossible to predict what will happen under any given set of physical conditions." The case of the vitalist depends wholly upon the overthrow of philosophical materialism. The problem of vitalism has thus become a philosophical one.

Many of the arguments used by vitalists do not appeal to the writer as intrinsically sound. I fully agree with R. S. Lillie ('14) and O. Glaser ('12) that the argument of the insufficiency of mechanism to "explain" everything has been much overworked. And yet there are a few considerations of this sort which seem to me to have some weight. Of these I will mention only two. The first is the difficulty of explaining the synthetic activity of the conscious mind on the basis of brain structure. One of the greatest weaknesses of mechanism in the field of physiological psychology is the lack of appreciation of the synthetic and correlating activity of human consciousness (will).

The other difficulty relates to the phylogenesis of the rational human individual. Is it possible for us to believe that a chaos has become a cosmos without the effective cooperation of a directive intelligence or will? Is it possible to believe on rational grounds that a material universe devoid of mind has produced a mind capable of judging mechanism? Says J. J. Putnam:

> If this were true it would seem possible for a man to lift himself by his boot-straps. But if it be impossible for mechanism (unguided by in-

telligence) to produce the mind of a person capable of judging mechanism, it is clear that mechanism has not been the only principle at work in the evolutionary process.

If Dr. Putnam's contention is sound, it becomes possible to understand the point of view of the modern theologian when he says:

Never yet has something come out of nothing. Never yet has order arisen out of confusion or light out of darkness as a result of anything other than personality. Force, law, life and achievement carry the mind irresistibly to the supreme will, to the supreme life, to the personality of God. A universe teeming with mind, fired within and stamped without with intelligence is the attestation of the living God. God is the meaning of the universe (Gordon, '10).

The acceptance of the idealistic postulate and of the point of view of the neo-vitalist make it possible to understand Dr. Gordon when he says further:

Behind all human achievement we see the creative spirit at work. Back of all achievement in literature we see the personality of Homer and Æschylus, Dante, Goethe and Shakespeare. Behind the achievements of the race in art we see the personality of Praxiteles, Raphael and Michael Angelo. For the entire high achievement of the race there is no explanation but the creative spirit of human personality. In our contemplation of nature and in our attempt to comprehend it we need to carry with us the sense of creation. The universe is the supreme achievement. Behind this achievement is the infinite soul and as our human world is a living and expanding achievement, we must conclude that within it is the creative spirit of God.

That scientific men occasionally catch a glimpse of the theological viewpoint seems borne out by the following quotations:

There is a wider teleology which is not touched by the doctrine of evolution, but is actually based upon the fundamental proposition of evolution (Huxley).

We are beginning to see the ascent of the Ideal of evolution. Thus biological science must indeed become the handmaid of religion (Thomson and Geddes).

Supposing that in youth we had been impregnated with the notion of the poet Goethe, instead of the notion of the poet Young, looking at matter not as brute matter, but as the living garment of God, is it not probable that our repugnance to the idea of the primeval union between spirit and matter might be considerably abated? (Tyndall).

I see everywhere the inevitable expression of the Infinite in the world (Louis Pasteur).

In whatever direction we pursue our researches, whether in time or space, we discover everywhere the clear proofs of a Creative Intelligence (Sir Charles Lyell).

We are unmistakably shown through nature that she depends upon one ever-acting Creator and Ruler (Lord Kelvin).

I can not imagine the possibility of any one with ordinary intelligence entertaining the least doubt of the existence of a God (William Crookes).

Matter and energy have an original property, assuredly not by chance, which organizes the universe in space and time. . . . If life has originated by an evolutionary process from dead matter, that is surely the crowning and most wonderful instance of teleology in the universe (L. J. Henderson).

If then for the reasons advanced we are to accept the idealistic postulate as the basis of our discussion of individuality, what will be the effect upon the mechanistic interpretation? How wide is the sphere of the mechanist? Just as wide as he used to think before he converted a method of investigation into a complete philosophy and interpretation of life. Most of our lives are mechanistic as we have always believed them to be. A large part of that which is not mechanistic is deterministic. For we are bound by heredity, hormones and habit.

Such limitation—such determinism—is the essential condition, as Palmer ('11) has well said, of that little measure of vitalistic freedom which we actually enjoy. The laws of determinism rule our lives more than the vitalist has been willing to believe. But we are free to choose between two alternative lines of necessity and to that extent at least our fates are in our own hands.

The study of animal behavior justifies the inference that consciousness is effective in them as in man. But to a far greater degree are their lives mechanized. Those of plants appear to be wholly so, whatever they may once have been.

I have made this plea for a rehearing of the case of the vitalist, knowing full well that his is not a popular cause among my scientific colleagues. The reasons why I have done so have been presented. No one realizes more than I the liability of error involved, for I am far from familiar fields of investigation. If I am in error, past experience has taught me that the error will soon be discovered and pointed out by those with whom I differ, and the truth which we all seek will be advanced.

But by no means should men of science play the part of the theologians of the fifties. The spirit of science is not dogmatic. And yet extremes meet and sometimes the spirit of the twentieth-century scientist matches that of the theological dogmatist of the nineteenth. For when Minot ('02) maintained the thesis that consciousness must have been a factor in evolution his paper aroused such bitter opposition that one scientific colleague, who by his prejudices was wholly incapable of appreciating the fundamental strength of Minot's position, had his copy of SCIENCE bound mutilated by leaving out the number containing Dr. Minot's address. He did this on the ground that as a friend of Dr. Minot's he did not wish to perpetuate a paper which would undermine Dr. Minot's reputation as a scientific man.

The objectionable thesis of Minot's was as follows:

> It seems to me inconceivable that the evolution of animals should have taken place as it actually has taken place unless consciousness is a real factor and dominant. Accordingly I hold that it actually affects the vital processes. There is, in my judgment, no possibility of avoiding the conclusion that consciousness stands in immediate causal relations with physiological processes. To say this is to abide by the facts, as at present known to us, and with the facts our conceptions must be made to accord.

In justice to the zoologist who did what he could to obliterate all traces of Dr. Minot's paper, it is only fair to say that science has every reason on the basis of experience to regard such "vitalistic" views as "dangerous" from the standpoint of mechanism, because of the constant temptation to pass in explanation over into the psychological field—in other words, to revert to primitive modes of explanation. Therefore, to the person under discussion Dr. Minot may have seemed indeed a traitor to science.

But this is, I am sure, a most exceptional case, and quite anachronous. The spirit of the scientist is not the intolerant spirit of the partisan. Every biologist may be expected to treat the cause of the vitalist as if it were his own cause and grant him the rehearing in the court of philosophy which he now demands. In the discussion of this problem as believers in the scientific method it is our duty to set forth "that calm, fair-minded, tolerant spirit" which has characterized the thought of scientific men in the past. This—the scientific—spirit means, as President Vincent has said:

> an attitude of open-mindedness towards all truth; a determination to get all the essential facts before forming a judgment; a willingness to abandon a position when it is no longer intellectually tenable; a tolerance of the opinions of others which are to be accounted for rather than derided or denounced. This spirit is free from acrimony, blind partizanship and prejudice—the spirit which seeks the truth which makes men free.

If, then, the question of vitalism is to be discussed at all in our classrooms—I know of none where this interminable problem is not mentioned—and, if because of conscience's sake we are unable to accept the postulate of idealism, we may nevertheless

give the question fair, impartial and scientific treatment. Such treatment, I am compelled to believe, can not be given without full consideration of the basic principles upon which the discussion has been based. Adequate treatment it can not receive upon the materialistic assumption only. For, as has been shown above, the adoption of this postulate begs the whole question under discussion and precludes the possibility of a vitalistic interpretation of individuality. Therefore, if we must adopt this postulate for ourselves, we ought at least to present the problem as viewed from the standpoint of idealism which clearly admits of the possibility of the vitalistic interpretation, and give our reasons for the rejection of the idealistic assumption. Moreover, failure to set forth the implications which grow out of the acceptance of materialism or idealism would appear to mean the omission of considerations of great importance bearing on the question. But above all let us rid our minds of the wholly erroneous notion that the cause of mechanism demands the postulate of philosophical materialism; and, in case we are vitalists, let us free ourselves for the equally fallacious belief that the mechanistic interpretation of the physical aspect of individuality is irreconcilable with the vitalistic interpretation of *life as a whole*. Like the Darwinian and Lamarckian hypotheses the mechanistic and vitalistic hypotheses are complementary and not irreconcilable interpretations of individuality.

The general purport of this paper, therefore, is well expressed in the words of Professor H. W. Rand ('12, p. 850):

> Science will never solve its problems—at most, it will never do more than think it has solved them—unless it constantly realizes its own limitations and unless it frequently assures itself of the security of its foundations. Now, perhaps more than at any other time, the natural scientist stands in need of help which may well come from the philosopher. Is it not timely to raise the question as to the validity of the assumptions upon which science rests and the integrity of the methods by which we attempt to progress?

Says Rogers ('09):

> It is no unusual thing for human reason to complete its speculative edifice in such haste that it forgets to look to the stability of the foundation.

SUMMARY

A. *The Scientific Problem of Individuality Vitalism vs. Mechanism.*—As formulated by Jennings ('14, p. 17) the problem reads:

> Is individuality a phenomenon not determined by the perceptual conditions, but requiring to account for it the agency of a non-perceptual agent?

There are two historical answers:

1. *The Thesis of Vitalism.*—That "individuality is a phenomenon not determined by the perceptual conditions only."

2. *The Thesis of Mechanism.*—That "individuality is a phenomenon determined by the perceptual conditions only."

1. The *Argument of Vitalism* is based on the assumption that either:

(a) The organic individual is in reality monistic, spiritual, a "Will" of "Ego" having material (bodily) manifestations, integrated and individualized not only by a central nervous system and by hormones, but (in the case of human individuality) by a "Will," also. "Will" is the unique characteristic of the individual (personality);

The formula for the individual is: $W(b)$; or, as some vitalists assume,

(b) The individual is in reality dualistic, a united will and body.

The dualistic formula for the individual is: $W + B$. The vitalist concludes that individuality (personality) is a phenomenon not determined by the perceptual conditions alone, but requiring to account for it the agency of a non-perceptual agent.

2. The *Argument of Mechanism* is based upon the assumption that:

The organic individual is in reality monistic and material—a body with epiphenomenal mental manifestations. Unity is effected by means of a central nervous system and hormones uninfluenced by a "Will."

The formula for the individual is $B(w)$. The mechanist concludes that individuality (personality) is a phenomenon determined by the perceptual conditions alone. Now, since obviously the conclusion of vitalist and mechanist is not logically deduced, but simply restates the fundamental assumption made, and since the conclusion, therefore, is true only if the assumption is true, and, since the truth of the assumption is a philosophical problem.

The Case of Vitalism *vs.* Mechanism must now be carried to the higher court of philosophy, which has jurisdiction over such cases.

We are therefore compelled to take up—

B. *The Philosophical Problem of Individuality—Idealism (Spiritualism) vs. Materialism.*—What in reality is the basis of individuality in organisms? Is the individual a material body of various properties, and nothing more? Is the basic principle of life spiritual, or material, in reality?

1. The basic assumption of mechanism (materialism) is, that—The individual (human personality) is in reality monistic and material, a body with epiphenomenal mental manifestations, and that individuality is expressed by the formula $B(w)$. Now, since this assumption is found upon analysis by philosophers to be unscientific (unknowable), useless (to the mechanist as well as to others), unnecessary (on logical grounds) and metaphysical, and since it states or interprets the known (*i. e.*, experience) in terms of the unknown and knowable (real substance, independent of consciousness), this materialistic assumption is rejected by modern philosophers.

Consequently, if the opinion of experts is to be respected, and if, therefore, we must regard the materialistic assumption as false, then we are compelled to reject the conclusion of the mechanists that an interpretation of individuality (personality) in mechanistic terms alone is adequate to experience. For false premises mean false conclusions.

The acceptance of the idealistic (spiritualistic) assumption by modern philosophers compels us to accept it.

It seems necessary, therefore, to conclude that the vitalist is correct in asserting that not all of personality is spatially expressed. In other words,

Individuality (personality) is a phenomenon not determined by the perceptual conditions only, but requiring to account for it the agency of a non-perceptual agent.

This agent is the "Ego" or "Will." The formula of individuality therefore, is: $W(b)$, and the vitalistic theory "ist noch nicht aus dem Welt geschafft."

And, unless by caprice or prejudice we refuse to trust the opinion of experts and adopt a discredited philosophy as the foundation of our thought, vitalism will continue to be our interpretation of individuality in organisms, although *not, of course, in the mechanistic aspects of individuality.*

H. V. NEAL

TUFTS COLLEGE

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GUSTAV SCHWALBE

THE death is announced of Professor Doctor Gustav Schwalbe, one of the most distinguished anatomists of Germany, who, established in recent years his leadership in the subject of human anatomy through his broad and profound knowledge of comparative anatomy. His analysis of the human remains of the Lower Paleolithic, beginning with the type Neanderthal skull, resulted in the recognition of *Homo neanderthalensis* as a distinct species of the human race. This has been followed by many other penetrating studies from which an entirely new system of cranial measurements has been deduced, namely, an internal system which takes account of the proportions of the brain in place of the external system of Brocca and the older anatomists based on the superficies of the skull. Following the lamented death of Eberhard Fraas, the paleontologist, the loss of Schwalbe will be severely felt in the University of Strassburg. All those who enjoyed the pleasure of the acquaintance of this distinguished anatomist and who recall his genial and modest personality will deeply lament his death.

HENRY FAIRFIELD OSBORN

THE RURAL ROADSIDES IN NEW YORK STATE

BY investigations just completed by the New York State College of Forestry at Syracuse, it has been found that nine tenths of the roadsides in the rural districts of New York state are entirely void of shade trees. When this is considered along with the fact that last year New York state paid out of the state treasury about $30,000,000 for the construction and maintenance of roadbeds, it shows that the state is not yet awake to the great need and the great possibilities in rural roadside improvement.

The preliminary survey which has just been made by H. R. Francis in charge of the landscape extension work of the College of Forestry, covered nearly 3,000 miles of the main lines of highways passing through such important points as Rochester, Buffalo, Jamestown, Olean, Hornell, Corning, Ithaca, Cortland, Elmira, Binghamton, Oneonta, Kingston, Hudson, Albany, Schenectady, Glens Falls, Lake Placid, Malone, Potsdam, Watertown, Utica, Rome and Syracuse.

During the survey studies were made of such important features in rural roadside improvement and beautification as good and bad varieties of trees found along the highways, views and vistas obtained from the highways, the effects of the shade trees on crops in adjacent fields, the possibilities of the covering of barren embankments and the planting of some desirable sort of vegetation where overhead wires are in large numbers. One of the principal features studied was the condition of the roadbed as affected by the presence or absence of shade trees.

A detailed study of the main state highway east and west between Albany and Buffalo will be made immediately by the State College of Forestry. The observations which have already been made in all sections of the state together with the information obtained by the detailed study will be used as a basis for an educational publication to be issued by the college and distributed very widely to organizations in the state, such as the automobile clubs, women's clubs, commercial associations, granges, farm bureaus and the State Forestry Association and other individuals interested in this development.

This is the first comprehensive study to be made of the landscape treatment of the rural roadsides in the state and the college predicts a wider appreciation of the possibilities and the necessity for the planting and preservation of forest trees along the rural roadsides. Few people in the state will be able to visit the wonderful national parks of the west, but an increasing number of people will own automobiles and use the highways of the state. Many if not all of these highways may easily become state park ways of beautiful trees and

shrubs. Trees grow like weeds under the climatic conditions existent in New York and with varied scenery of intense interest the highways of the state will eventually become as beautiful as those of any other state in the union.

THE NEW YORK MEETING OF THE AMERICAN CHEMICAL SOCIETY

A meeting of the American Chemical Society will be held in conjunction with the Second National Exposition of Chemical Industries, September 25 to 30, inclusive. A council meeting is called for Monday afternoon and Monday evening. A general meeting follows on Tuesday morning, and on Tuesday afternoon it is hoped to have a public meeting in the large hall at the City College, with addresses by prominent men bearing upon "Chemistry and the National Welfare." On Tuesday evening a general "get-together" entertainment will be given by the New York Section complimentary to the parent society, to which visiting chemists will be invited. On Thursday evening the Electrochemical Society will give a smoker, to which the members of the American Chemical Society will be invited, and on Friday evening a subscription banquet will be held in one of New York's large hotels.

Meetings of divisions will be held on Wednesday, Thursday, Friday and Saturday mornings. One of the special features of the meeting will be general conferences on special subjects in which the chemists of the country are now interested. The idea of these conferences is to have some important topics such as

Glassware and Porcelain,
Steel Alloy Metals,
Paper and its Utilization,
Oils and Motor Fuels,
Convertibility of Plant,
Medicinal Chemicals,
Dyestuffs and their Relation to Munition Factories,
Industrial Alcohol, Acetone and Formic Acid,

the discussion to be started by some well-known specialists in these lines. No set program is planned for these conferences, but it is believed from past experience that chemists interested in these various lines will get together and many interesting points will be brought out which will be of mutual interest. The topics for these conferences have not as yet been determined upon, and suggestions are desired from members of the society. These suggestions will all be placed before the Program Committee, and some six or eight topics selected therefrom. It is anticipated that two conferences will be in session each afternoon at the same time, one in the lecture hall of the Grand Central Palace, where the Second National Exposition of Chemical Industries will be held, and one in the lecture hall of the Chemists Club.

The president's address will be one of the general papers at the public meeting on Tuesday. The division of biological chemistry, physical chemistry and industrial chemistry will hold a joint symposium on colloids on Wednesday and Thursday mornings. On Wednesday morning the symposium will be of a theoretical nature, in which the industrial division will not take part. On Thursday morning the symposium will be composed of industrial application of colloid chemistry. A symposium on occupational diseases is also planned and is to take up part of one of the morning sessions of the industrial division.

SCIENTIFIC NOTES AND NEWS

A memorial to Major Walter Reed, of the army, who demonstrated the transmission of yellow fever by mosquitoes, is planned for the campus of the University of Virginia, of which he was a graduate.

Professor Julius Stieglitz, of the University of Chicago, and Dr. Leo Baekeland, of New York, were given the honorary degree of doctor of chemistry by the University of Pittsburgh at its recent commencement.

The degree of D.C.L. has been conferred by the University of Oxford upon Douglas William Freshfield, M.A., University College, president of the Royal Geographical Society.

Dr. Charles H. Mayo was the guest of honor at a banquet given on June 22, by the citizens of Rochester, in recognition of his

election as president of the American Medical Association. A silver loving cup was presented to Dr. Mayo.

DR. ALBERT SHIELS, director of the bureau of reference and research of the New York City Board of Education, has been elected city superintendent of schools of Los Angeles at a salary of $8,000 a year. The salary formerly paid the city superintendents there was $6,000 a year.

DR. A. A. EISENBERG, formerly pathological anatomist in the U. S. Army Medical Museum and School, Washington, D. C., has been appointed pathologist at Charity Hospital, Cleveland.

PROFESSOR B. E. LIVINGSTON and Dr. H. E. Pulling, of the laboratory of plant physiology of the Johns Hopkins University, will spend the months of August and September in the region of Fort Churchill and Port Nelson, Hudson Bay. They will carry out field studies of vegetation as related to soil and climate.

MISS ALICE EASTWOOD, curator of the botanical department of the California Academy of Sciences, spent five days, from June 15 to 20, collecting at the Grand Canyon of the Colorado. The Hermit Trail was traveled to the bottom of the canyon, and the Grand View or Berry Trail for about two miles down. The Bright Angel Trail had been explored previously by Miss Eastwood. About 270 species were collected.

PROFESSOR GEORGE NEILL STEWART, director of the Cushing Laboratory of Experimental Medicine, Western Reserve University, will sail for England on July 22.

MISS ETHEL GERTRUDE EVEREST, of Chippens Bank, Hever, Kent, daughter of the late Colonel Sir George Everest, surveyor-general of India, has left the house on her estate to the National Trust to be used as a home of rest for tired brain-workers, particularly writers and artists. The land round the house has also been bequeathed to the National Trust to be used as a public park for the use of the nation, and as a "bird sanctuary," where bird-life shall be encouraged, together with £8,000 for the maintenance of the estate.

DURING the week of September 25 the Second National Exposition of Chemical Industries will be held in New York. The American Electrochemical Society will be one of the national societies which will meet in New York during the same week. Its meetings will be held on September 28, 29 and 30, and the outline of the program has just been announced. It is as follows:

Wednesday, September 27, evening: General reception, with registration at the Chemical Exposition, Grand Central Palace.

Thursday, September 28, forenoon: Reading and discussion of papers, general subject: "Made in America."

Afternoon: Visiting the exposition.

Evening: Complimentary smoker. An invitation will be extended to the members of the American Chemical Society and other visiting chemists and engineers.

Friday, September 29, forenoon: Reading and discussion of papers.

Afternoon: Visiting the exposition.

Evening: Subscription dinner-dance.

Saturday, September 30, forenoon: Reading and discussion of papers.

Afternoon: Visiting the exposition.

THE graduates of the course in public hygiene of the University of Pennsylvania have recently organized as an Alumni Association. The university was a pioneer in the field in this country and has been offering instruction for public health positions since 1906. In 1910 they graduated their first doctor of public hygiene, Dr.P.H., and at present the graduates of this course number twenty-six physicians, with the degree Dr.P.H. and two engineers with certificates as certified sanitarians. Of the physicians three are women. These graduates are widely scattered, in India, Siam, China, Philippine Islands, Hungary and England, in the United States from California to New Jersey and in the U. S. Army and Navy medical services. Their occupations range from medical missionaries through scientific research, epidemiology, sanitary engineering, municipal health officers, labor departments, housing commission and tuberculosis prevention work to special hospital work and teaching in public health and allied lines.

Recent appointments to the Office of Investigations in Forest Pathology, Bureau of Plant Industry, are as follows: Samuel B. Detwiler, formerly field superintendent of the Pennsylvania Chestnut Tree Blight Commission, has been appointed forest inspector in charge of field work on the white pine blister rust. Reginald H. Colley, lately assistant professor of botany in Dartmouth College, and Minnie W. Taylor, lately assistant in botany in Brown University, have been appointed agents to assist Dr. Perley Spaulding in research on the white pine blister rust. Paul V. Siggers, lately a graduate student in botany in the University of Michigan, and Gilbert T. Posey, research assistant in botany at the Oregon Experiment Station, have been appointed scientific assistants to Mr. Detwiler. George L. Barrus and Norton M. Goodyear, recently engaged in commercial forestry, have been appointed agents also assisting Mr. Detwiler. In addition to these more or less permanent appointments, about forty field agents have been appointed for temporary periods to work on the white pine blister rust in cooperation with various state officials. Field work on the white pine blister rust east of Ohio is organized under the general direction of Mr. Detwiler; west of and including Ohio, under the general direction of Mr. Roy G. Pierce.

Sir Ernest Shackleton, who, on returning from the South Polar zone last April, left twenty-two of his companions on Elephant Island, sailed on July 18 from Punta Arenas, Chile, on a small schooner, hoping to rescue them. If conditions are favorable, Sir Ernest expects to relieve the explorers and to return to Chile in four weeks.

The final meeting for the session of the University of Pennsylvania Chapter of the Society of the Sigma Xi, was held in the electrical engineering department, President E. C. Kirk presiding. Addresses on "Illumination" were given by Professor C. L. Clewell, from the engineering standpoint, illustrated, and by Professor George E. de Schweinitz, from the standpoint of the ophthalmologist. The following officers for 1916–17 were elected: *President,* Warren P. Laird, professor of architecture; *Vice-president,* C. E. McClung; *Treasurer,* J. Percy Moore; *Recording Secretary,* S. P. Shugert; *Corresponding Secretary,* W. H. F. Addison.

Plans are now being completed for the eighty-sixth annual meeting of the British Association, this year to be held at Newcastle-on-Tyne in the first week of September, as has been already noted in Science. Sir Arthur Evans, the archeologist, taking the chair in succession to Professor Arthur Schuster, will deliver his presidential address on September 5. This year's sectional presidents will be: Mathematical and Physical Science, Professor A. N. Whitehead, of the Imperial College of Science; Chemistry, Professor G. G. Henderson, Glasgow; Geology, Professor W. S. Boulton, Birmingham; Zoology, Professor E. W. Macbride; Geography, Mr. D. G. Hogarth, keeper of the Ashmolean Museum, Oxford; Economic Science and Statistics, Professor A. W. Kirkaldy; Engineering, Mr. G. G. Stoney, Newcastle; Anthropology, Dr. R. R. Marett; Physiology, Professor A. R. Cushny, University of London; Botany, Dr. A. B. Rendle, of the British Museum; Educational Science, the Rev. W. Temple, rector of St. James's, Piccadilly, and formerly headmaster of Repton School, and Agriculture, Dr. E. J. Russell, director of the Rothampsted Experimental Station at Harpenden. Evening lectures will be given by Dr. Chalmers Mitchell, secretary of the Zoological Society, on "Evolution and the War," and by Professor W. A. Bone on "Intensified Combustion."

Major R. Tait Mackenzie, R.A.M.C., professor of physical education, University of Pennsylvania, opened a discussion on the necessity for a national scheme of physical education, at a meeting of the Royal Sanitary Institute, at the Municipal School of Technology, Manchester, on July 7.

The collection of ethnological remains brought from South America by Dr. W. C. Farrabee will require more than three months to arrange, and therefore will not be on exhibition until next fall. The expedition, which was headed by Dr. Farrabee, extended over a

period of three years, and cost more than $100,000.

UNIVERSITY AND EDUCATIONAL NEWS

THE Yale University School of Medicine will receive $14,845 by the will of Norman B. Bayley.

THE new master of Magdalene College, Cambridge, Mr. A. C. Benson, has established a Charles Kingsley lectureship in natural science in the college with an income of £150.

A SCHOOL of applied social sciences will be opened at Western Reserve University, at the beginning of the next academic year. It will be a graduate school with a two-year course, in which supervised field work will be an essential part of the plan.

AT the University of Cambridge the proposed grace relating to the admission of women to the first and second M.B. examinations and the examination in architectural studies has been withdrawn, in order that reports on the subjects may be presented to the senate by the boards concerned.

MR. J. H. HILL has been appointed professor of mathematics at the Ohio Northern University.

R. L. DAUGHERTY has been appointed professor of hydraulic engineering at Rensselaer Polytechnic Institute. He has for the past six years been assistant professor of hydraulics in Sibley College, Cornell University. He succeeds at Rensselaer Professor Lewis F. Moody who has gone into private practise. Professor Daugherty is the author of "Hydraulic Turbines," "Centrifugal Pumps" and "Hydraulics." He graduated from Leland Stanford University in 1909 and was an instructor in experimental engineering there the following year.

THE following appointments have been made to the medical faculty of New York University: clinical professors of surgery, Drs. Joseph B. Bissell, Thomas A. Smith, Walter C. Cramp and Arthur M. Wright; professor of clinical surgery, Dr. William C. Lusk; chief of clinic, department of surgery, college dispensary and instructor in surgery, Dr. W. Howard Barber; instructor in surgery, Dr. George Francis Cahill; clinical professor of medicine, Dr. Theodore J. Abbott; instructor in medicine, Dr. Hubert V. Guile; clinical professor of cancer research, Dr. Benjamin M. Levine; assistant professor of bacteriology and hygiene, Dr. Charles Krumiede, and instructor in bacteriology, Miss Mary Smeeton.

DISCUSSION AND CORRESPONDENCE

BEES AND MENDELISM

SOME confusion of thought as regards Mendelian expectations is apparent in Mr. Quinn's article[1] dealing with his interesting observations on the inheritance of body color in crosses of Italian with Caucasian bees. Mr. Quinn considers that his observations are not in accord with those of Newell because the latter concluded that "the production of an F_1 (heterozygous) drone seems to be an impossibility and this, in turn, makes the production of a strict F_2 generation look like another impossibility." But Quinn reports obtaining a typical 1:2:1 ratio of pure yellow: heterozygous yellow: pure gray queens in F_2, which he considers evidence that the drones as well as the queens of the F_1 generation are heterozygotes. This would indeed be true if a single F_1 queen mated with a single drone gave the result stated. But Quinn does not so report the facts. His statement apparently applies to the F_2 queens considered collectively, not to those produced by a single F_1 mother. If, as both Newell and Quinn suppose, all F_1 queens are heterozygotes and produce equal numbers of I and C gametes, and if they are mated some with pure I and others with pure C drones, then the expectation as regards their female offspring is that actually observed by Quinn. For a mating with a pure I drone should produce 1 II + 1 IC zygotes; and a mating with a pure C drone should produce 1 IC + 1 CC zygotes; and if the two kinds of matings are equally productive, their combined result would be 1 II + 2 IC + 1 CC, as reported by Quinn. It is therefore unneces-

[1] SCIENCE, June 30, 1916.

sary to assume from the facts reported that the drones of the F_1 generation are heterozygous as regards color. If this fact were established, it would disprove the Dzierzon theory, which is supported by so many distinct lines of evidence and thus far contradicted by none. A very direct test of the assumption that F_1 males are heterzygous could be made by mating them with queens of pure race. Such matings should produce mixed broods, if the drones are indeed heterozygous, but otherwise not.

We may conclude that the facts reported by both Newell and Quinn are credible since (1) they are really not at variance with each other, (2) they have been made independently by experienced observers in the wonderfully favorable environment of Texas and (3) their observations accord with previous knowledge. The credibility of Quinn's report is increased, not lessened, by the fact that he supposed his observations were at variance with prevalent theories.

Quinn's observations do not call in question the Mendelian inheritance of yellow body-color in crosses, but Newell reported some facts which might lead one to doubt the completeness of segregation in all cases, such as the production of drones of intermediate color. The orthodox Mendelian and the devotee of "exact" heredity will probably close his eyes to such troublesome facts, but the student of heredity who is not convinced of the finality of present knowledge might do well to keep them in view.

William E. Castle

Bussey Institution,
July 1, 1916

NOTE ON A MORAINE IN NORTHWESTERN NEW ENGLAND[1]

A recessional moraine consisting of several separate segments disposed along a sinuous course lies near the Atlantic coast, and has been traced through 60 miles from Saco, Maine, to Newbury, Mass. It stands for the most part at about or less than 100 feet above sea level, but rises to 150 feet in Dover, N. H., and Newburyport, Mass., and to between 200 and 250 feet in Wells and South Berwick, and although not more than 40 to 100 feet higher than surrounding Pleistocene formations, it is topographically prominent. The moraine rests upon and is surrounded by a floor of ice-smoothed rock and of till. During the building of the moraine the region was submerged so that the ice front stood in the sea. The moraine is the result of accumulation of glacio-fluvial detritus discharged directly into the sea; consequently in some places it is built up as broad, flat, delta-like plains. Clay ("Leda clay") which is glacial outwash was continuously deposited in the sea both while the moraine was building and also after the ice retreated from the moraine, so that the younger clay beds in some places overlie the moraine. The moraine and the marine clay probably belong to a late Wisconsin sub-stage of the Pleistocene epoch.

Further description and discussion of this moraine will appear in a paper to be published by the United States Geological Survey.

Frank J. Katz

[1] Published by permission of Director of U. S. Geological Survey.

NEPTUNIUM

In response to Professor Emerson's request for information concerning this element I beg to present the following:

Neptunium was announced by K. Hermann in 1877 (Pharm. Central H., June 7, 1877, p. 186, through the *Proceedings of the American Pharm. Assn.*, 1877, p. 268).

It is described as belonging to the "tantalum group," of the atomic weight 118, and as occurring in certain rare earths associated with tantalum and niobium.

J. F. Couch

Des Moines, Iowa

SCIENTIFIC BOOKS

Psychological Effects of Alcohol. An Experimental Investigation of the Effects of Moderate Doses of Ethyl Alcohol on a Related Group of Neuro-muscular Processes in Man. By Raymond Dodge and Francis G. Benedict, Carnegie Institution of Washington, Washington, D. C., 1915.

There is no more unsatisfactory chapter in the history of physiological psychology than that concerned with the action of alcohol. Most of the work on this subject has been done in the interests either of temperance or "beer," and shows in a striking, at times even in a grotesque, manner the failure so frequent in scientific work carried out with an immediate practical aim. It is therefore a matter for congratulation that the investigation of the physiological and psychological effects of alcohol should have been undertaken by so wholly independent a body as the Carnegie Institution and by an investigator so evidently free from practical as opposed to scientific interest as the director of its department of nutrition.

The book under notice, which is the first-fruits of this research, must be regarded as "survey" rather than "intensive" work, to borrow terms from another science. It covers an extensive field in which the action of ethyl alcohol is tested on a number of processes including the patellar and eyelid reflexes; the reaction of the eye to peripheral visual stimuli and the reaction-time in reading; the psychogalvanic reflex and the process of free association; the process of memorizing; the sensory threshold for faradaic stimulation, the velocity of eye-movements and of movements of the finger; together with observations on pulse-rate made concurrently with the other investigations.

The main result of the work is to show that wherever alcohol has an appreciable action, it is on the average depressing, and that this effect is greater on the simple motor, sensory and reflex processes than on those in which the higher parts of the nervous system are more directly involved.

The aim of the work has been to test the influence of alcohol upon a series of neuro-muscular processes. The authors have chosen for this purpose processes which they believe to be simple and customary with the avowed aim of excluding such factors as practise and interest. They hardly seem to have realized that the factors thus excluded are just those which from the title of the book we should expect to find the special object of study. The research is really one on neuro-muscular process preliminary to the study of the psychological effects of alcohol rather than such a study itself.

It is a question how far the authors have succeeded in their efforts to attain the simple. It is unfortunate, with this end in view, that they should have chosen the knee-jerk, for though this reaction is now generally regarded as a reflex, it is one of a very special kind, depending as it does upon a condition of muscular extension. Still less appropriate from this point of view are the observations which the authors have, not very happily, named after the process of reciprocal innervation and have regarded as tests of muscular coordination. It is unfortunate that in their search for the simple they should have chosen a process in which the examination of reciprocal innervation in Sherrington's sense involves a highly elaborate process of cortical activity. They have also departed widely from their principle of customary reaction for the movement of the finger which they measure is one of a highly artificial and unusual kind.

The foregoing criticisms are concerned with the general choice of the means by which neuro-muscular activity has been tested. With regard to the methods employed for this purpose the chief criticism to be offered is that the authors have depended too much on the time-relations of the processes they study and too little on their accuracy and on the adequacy with which the movements fulfil their functions. Otherwise little objection can be raised to the technique of the observations. In such survey work in which a number of subjects were employed, it was perhaps impossible to regulate their lives more completely and thus bring the research nearer to the ideal of the method of difference, but this regulation should not be neglected in more intensive work. Similarly, the disuse of control-mixtures is of little importance in work from which psychological factors have been so largely excluded, but it is to be hoped that this precedent will not be followed when psycho-

logical processes become the special object of research.

Less satisfactory than the experimental technique is the statistical treatment of the results. Serious objection must be taken to the misuse of the average. It is wholly misleading, for instance, to give 22 as the average of the three measurements, +85, −9 and −11. This figure is held to show that three so-called psychopathic subjects, *i. e.*, men who had been intemperate, did not differ to any extent from seven normal subjects. Really, the figures only show that of three formerly intemperate subjects one was far more sensitive than usual to the depressing effects of alcohol on the eyelid reflex, while the other two subjects resembled one out of the seven normal men in showing the stimulating effect of 30 c.c. of ethyl alcohol. This and other measurements on the intemperate subjects serve to confirm the statements made in their personal histories, that one was unusually sensitive to the influence of alcohol, while the others were less sensitive than usual, not, it is probable, on account of psychopathy, but through their former habituation to the action of alcohol. In so far as any weight can be attached to the apparently stimulating effect of alcohol in these two subjects, it may have been due to the satisfaction of a craving.

This work is the first contribution to an investigation of the action of alcohol which it is to be hoped may extend over many years and go far to settle a number of obscure and difficult problems. I have ventured to call attention to certain points of methodology and workmanship which seem to require reconsideration because in such an investigation principles and methods can not be too closely scrutinized at the outset. The criticisms now offered must not be allowed to obscure the recognition of the great value and promise of the work.

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Typical Flies—A Photographic Atlas of Diptera, including Aphaniptera. By E. K. Pearce. Cambridge (England), University Press, 1915.

This royal octavo, bound in boards, contains 4 pages of preface, 4 pages of classification; 45 pages of half-tone reproductions from photographs, comprising 155 figures representing 125 species distributed in various families, including 4 species of fleas, and 3 fly habitats; concluding with 2 pages of index. Under the figures are given technical name of the species, common name, if any, length of body, wing expanse, with brief data on habits and habitats.

The book is intended to fill the place of a pictorial elementary treatise. The plan is an excellent one, but difficult of proper execution. The author complains of the difficulties which he encountered in obtaining suitable material for photographic reproduction. Nevertheless, the figures are all quite recognizable, which is the main requisite to the success of the plan. The feature of including habitat photographs is commendable and might have been farther pursued.

There is no doubt that the wings and legs of flies must be spread in order to photograph them to the best advantage, but care must be exercised to secure natural attitudes, just as in the mounting of birds, mammals and other animals. Otherwise the reproductions are not true to nature but leave a marred image upon the memory, which appreciably reduces facility of recognition of the species in its habitat.

Recommendations made by the author in his preface regarding methods of mounting are open to objection. Aside from material for photographing, and the proper setting of the proboscis and hypopygium for study in certain forms, the reviewer decidedly favors leaving all flies in the natural attitudes assumed by them in the killing bottle. Specimens too small to be pinned with a No. 2 pin should be mounted on minute wire elbows wound on No. 3 pins. Only 34 to 39 mm. pins should be used, longer sizes giving trouble in the standard-depth cases. Great care should be taken not to get the specimen too high on the pin, but to leave sufficient room for grasping the head of the pin with the thumb and finger without danger of contact with the wings or other parts. There should be left sufficient space on the pin below the specimen for several labels, which

should be right side up that they may be read without the necessity of removing the specimen from the tray or case. In no instance should flies be gummed or mounted in any manner on cards, which are certain to obscure important characters.

Revision of other recommendations which occur in the preface should be made. Fine-mesh bobbinet is the proper material for nets; and white is the preferable color, facility of locating the fly in the net after capture outweighing any element of alarm to the fly prior to capture. In fact, the white net is very attractive to many flies, rare species often alighting thereon voluntarily in the field. As to size, the 22-inch diameter bamboo ring set in an unjointed three-foot light wooden handle is the most effective, specimens rarely escaping it even if the cast is made during flight. This is the net used by the veteran English field-naturalist, Mr. A. E. Pratt, in South America and New Guinea. It is sufficiently light to be easily wielded in one hand, and performs exceptional service.

The fly is best transferred directly from the net to the cyanide vial. The latter should be the 25 x 100 mm. flat-bottom clear-white shell vial, the cyanide enclosed in a wad of tissue paper and tightly wedged into the bottom, shredded tissue paper being placed loosely in the vial to prevent undue rubbing and contact of specimens, and closed with a soft cork stopper. Large and small flies should go in separate vials; such forms as bombyliids with pile that is easily detached must be kept separate, as well as culicids and other forms that might be injured by stouter flies or that might mess others with their scales, pile, exudations, or pollen. The judgment of the collector must guide him, and he should carry a liberal supply of the vials. The specimens may be left all day in such vials without injury, but should be pinned the same evening or at latest next morning. In dry climates they will not last well over night.

In giving measurements of flies, the length of one wing, and not the expanse, should be stated. The expanse is not a stable quantity, due to drying and faulty spreading; moreover, the wings of study material should not be spread.

As to the classification adopted, it is especially important to present a correct system in a work intended for beginners. Most systematists will criticize the inclusion of the fleas with the Diptera. The superfamily Muscoidea is made to include the entire calyptrate and acalyptrate divisions. The superfamily name *Cypseloidea* should be applied to the acalyptrate groups, while *Muscoidea* should be restricted to the higher calyptrates. The Muscoidea of the author are stated to produce ova as a rule, but there are very extensive groups of the higher calyptrates that deposit larvæ; in fact, the larvipositing species of calyptrates will probably easily exceed in number the ovipositing species. The Nematocera has recently been shown by Knab and others to be an unnatural group. In the pages of half-tone reproductions, the Cyclorrhapha are divided into Proboscidea and Eproboscidea, the latter comprising the Pupipara as opposed to all the other Cyclorrhapha; an unnatural arrangement, since the main Pupipara show close affinity with the Cypseloidea and not with the Syrphoidea. The Phoridæ are wrongly included in the acalyptrate series. The Bombyliidæ, and not the Braulidæ, are commonly termed "bee-flies."

With these few friendly criticisms, the book is commended as a very useful means of presenting objective instruction in dipterology.

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SPECIAL ARTICLES

A SIMPLE AND RAPID METHOD OF STUDYING RESPIRATION BY THE DETECTION OF EXCEEDINGLY MINUTE QUANTITIES OF CARBON DIOXIDE

IN order to arrive at a satisfactory knowledge of life-processes, it is necessary to have accurate quantitative methods by which the measurement of these activities can be made. One of the best means of accomplishing this is found in the study of respiration. The production of CO_2 is regarded[1] as the only reli-

[1] *Cf.* Tashiro, S., *Amer. Jour. of Physiology*, 32: 107.

able universal expression of respiratory activity in anaerobic and aerobic tissues in normal condition.

It is extremely important to possess a method of detecting very small quantities of CO_2 as it is given off by the organism in the normal environment. The excellent methods devised by Tashiro[2] for the detection of very minute quantities of CO_2 are unfortunately limited to the study of tissues which are not bathed by solutions. But many of the most important studies on respiration require that the tissues shall be immersed in solutions in order to measure the effect of dissolved substances on respiration. Moreover the methods of Tashiro do not enable us to determine the quantities of CO_2 produced from moment to moment as the reaction goes on and thus to construct the time curve, which is, in most cases, of primary importance.

These difficulties are overcome by the method here described. The method consists in adding an indicator to the solution containing the tissue and observing its color changes.

The indicator should possess the following qualities: (1) it should be non-toxic to the material; (2) it should not rapidly penetrate the tissues; (3) it should be sensitive to very slight increases in the hydrogen ion concentration due to CO_2; (4) it should have a suitable working range.

Phenolsulphone-phthalein with a range of color changes from PH^+ 6.5 to PH^+ 8.5 but with extremely sharp differentiations in color between PH^+ 7.0 and PH^+ 7.5, has been found to be very satisfactory.[3] Other indicators of various ranges of color change, such as phenolphthalein, alizarin sodium sulphonate, etc. (sulphonic acid salts being not readily absorbed by cells), are being studied as to their usefulness for such work.

When salts occur in the solutions used, the salt error for the indicator should be taken into account. Some indicators can not be used with certain salts on account of being precipitated out of solution, but experimentation alone can tell which, in the large list of accurately described indicators,[4] are best adapted to a particular need.

If the material is of the nature of seeds, algæ, or aquatic animals, the whole of which can be submerged, the following procedure is followed: A tube of non-soluble or Pyrex glass of the desired diameter and length (for small seeds, algæ, etc., 16 mm. diameter by about 4 to 5 cm. long is very satisfactory; tubes below 16 mm. diameter are not recommended) is closed at one end by fusion. A piece of rubber tubing about 7 cm. long is attached at the open end. It is best to boil the rubber tubing repeatedly previous to using it, in order to insure thorough cleanliness. The rubber tube, while attached to the glass tube, is dipped a few seconds into hot paraffin so as to put a thin coat on both sides of the rubber. The best grade of paraffin (58°–62° C. melting point) is used, and serves to prevent the rubber from possibly giving off substances to the solution and also is advantageous in giving a seal against the CO_2 of the air. Ordinary soft glass tubing (which gives off alkali) or parawax (which gives off acid) is not suited for accurate work. Pyrex tubes, in the absence of Jena glass, can be used to advantage, especially because all sizes can be obtained.

The material to be studied is placed in the glass tube with a definite number of c.c. of solution containing a definite number of drops of an indicator of known strength. The volume of solution used is always made as small as possible, consistent with the requirements for colorimetric work, but however small the volume of solution used, slightly more than enough to fill the glass tube must be taken. The paraffined rubber tube is then closed with two strong pinchcocks so as to exclude all air from contact with the solution. The paraffin on the rubber tube is prevented from becoming brittle before it is clamped, by working rapidly or if necessary by the use of a lukewarm water bath. In this case the CO_2 in the solution is

[2] Tashiro, S., *Amer. Jour. of Physiology*, 32: 137; *Jour. Biolog. Chem.*, 1914, p. 485.

[3] Lubs, H. A., and Clark, W. M., *Jour. Wash. Acad. Sci.*, Vol. V., No. 18, November 4, 1915.

[4] Höber, "Physik. Chem. der Zelle und der Gewebe," 1914, p. 171.

in equilibrium with the CO_2 of the air before the tube is clamped. The closed tube is inverted several times and the color of the solution is compared with a series of buffer solutions of known hydrogen ion concentration and the acidity at the beginning of the experiment is recorded. The tube can be put on a shaker, should conditions require it, and after any interval whatsoever, the tube is inverted a few times in order to stir the liquid and to get a uniform color throughout the solution and then by comparing it with the buffer solutions, the increase in hydrogen ion concentration is noted. This can be repeated any number of times and at any interval of time. Changes in the hydrogen ion concentration as small as from 2×10^{-6} to 1×10^{-6} can be detected in this way.

Much smaller differences in the hydrogen ion concentration of a solution can be detected by using distilled water nearly or entirely free from CO_2, or by using solutions in which the hydrogen ion concentration is low. The procedure when pure distilled water is used is the same as that just given except that while the tube is still in the bath ready for clamping, a CO_2-free gas is bubbled through the solution until, by comparison with the buffer solution, it is known that the solution in the tube is between PH^+ 7.0 and PH^+ 8.0. The tube is then clamped off as before and the hydrogen ion concentration is read at intervals by comparison with buffer solutions. If the solutions, due to added reagents, are quite acid, then the smallest amount of CO_2 that can be detected is increased. However it is often possible to add the same amount of alkali to each tube so as to decrease the hydrogen ion concentration at the start and in this event the method can become extremely sensitive so as to detect minute traces of CO_2. This is also true of many solutions in which the hydrogen ion concentration is very small.

When the respiration of roots is studied, the glass tube has both ends open and tubing on each end. The roots are inserted into one (very short) paraffined rubber tube, and by means of a pinchcock, the tube is clamped so that only a small space is left about the stalk as it protrudes. A low melting mixture is used to make the final seal about the plant. After the plant has been inserted, the paraffined tube is attached at the other end. The solution is then run in and the CO_2 expelled by bubbling hydrogen through. The paraffin, before clamping takes place, should be rather soft and pliable, and should it tend to become brittle it can be kept soft by being kept inside of a tube open at both ends and which is kept warm by a surrounding water bath. After clamping, readings are made as usual.

When the liquid used is pure distilled water, and is quite free from CO_2, a change in the hydrogen ion concentration as small as from 2×10^{-8} to 3×10^{-8} can be noted. The smaller the hydrogen ion concentration of the solution at the start of the experiment, the more minute the differences which can be detected. If the experiment is started with the solution in equilibrium with the CO_2 of the air, it is possible to ascertain whether or not the increased acidity has been due to the giving off of CO_2 or to acid excretions other than CO_2, by pouring the solution into another tube and (after shaking without the material) letting the solution come again into equilibrium with the air, and noting whether or not the solution returns to its original hydrogen ion concentration. Furthermore, by bubbling a CO_2-free gas through the solution at the end of the experiment and through a sample of the original solution, it is possible to find out whether acids other than carbonic acid have been given off. If at the end of an experiment it is found that acids other than carbonic acid have been given off, or that an unequal absorption of ions has taken place, so as to produce acidity, then the increase in the hydrogen ion concentration due to CO_2 can be obtained by subtraction. As it is important to know whether acids other than carbonic are given off by plant and animal tissues, experiments have been conducted upon the excretion of acids by plant tissue, the results of which will appear at a later time.

When it is desirable not to have the indicator in the solution during the experiment,

the method can be modified as follows. One end of the glass tube has a paraffined plug having two holes, while the other end has the usual paraffined rubber tube. One hole can be sealed shut if no stem is to protrude, while in the other hole a small glass tube containing the required number of drops of indicator is inserted with a solid glass plunger of equal diameter adjoining, and protruding from the plug. At the end of a given time the indicator is pushed into the solution by means of the airtight plunger and the reading is made rapidly. In such a modification, control tubes must be depended upon to give the hydrogen ion concentration of the solution at the start of the experiment, and, moreover, only one reading can be made from a single tube.

Pure block tin collapsible tubes have been found to be very useful but are very difficult to seal as compared with the paraffined rubber which is easily sealed. Experiments with seeds were run for an hour without any change in the control, and even though it may be possible to run experiments a much longer period without change in the control, yet it appears advisable to cut down the time of an experiment whenever possible; this the new method permits.

In making up buffer solutions,[5] the writer has found it advisable to recrystallize chemically pure salts several times, and whenever possible it is best to check up the accuracy of the buffer solutions with the aid of the hydrogen electrode.

The writer has found that a constant source of light such as has recently been described in Science[6] is almost indispensable for this work.

By using seeds with the coats removed and a relatively small amount of solution a color change can easily be detected within five minutes.

By this method we can compare the respiration of organisms in different solutions with great accuracy without knowing the actual amounts of CO_2 given off. We need only to compare the times required to produce the same change of color in the solutions. If we use a substance in solution which affects the change of color in the indicator, this substance must be added to the set of buffer solutions. If, for example, we are studying the effect of NaCl on the respiration of roots we put one lot of roots into a solution of NaCl and another lot into distilled water. We then prepare a set of buffer solutions to which we add NaCl so as to make its concentration the same as in the solution containing the roots. We add the same amount of indicator to the solution containing the roots and to the buffer solutions, and the changes of color are then comparable. We proceed in the same way with the distilled water or with any other solutions employed.

If we wish to know the actual amounts of CO_2 given off we may calibrate the indicator by a very simple method, as yet unpublished, due to Henderson and Cohn. We may then use an indicator which passes through a well-defined series of color changes as the amount of CO_2 increases. By observing these changes we can plot the amount of CO_2 against time. The resulting curve enables us to study the dynamics of the reaction and this is of primary importance for an understanding of the processes involved in metabolism.

[5] Michaelis, L., "Die Wasserstoffionen-Konzentration."

[6] Science, N. S., 42: 764, 1915.

SUMMARY

1. Respiration may be accurately followed by observing changes in the color of indicators added to solutions which contain organisms.

2. Exceedingly small amounts of CO_2 may be determined in this way with great accuracy.

3. As changes in color often occur in five minutes, the experiments may be shortened so as to exclude pathological changes in the organisms.

4. The simplicity of the apparatus makes it possible to carry on a large number of experiments at the same time.

5. The amounts of CO_2 produced in successive intervals can be determined without disturbing the organism. This enables us to study the dynamics of the process.

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